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ABSTRACT

This paper describes functions of the components of hearing aids and provides a detailed procedure to detect hearing aid dysfunctions. The most common type of hearing aids for school children are the behind the ear type. Various hearing aid components change sound into an electrical signal, which is amplified and adjusted by a volume control. The resulting sound is then conducted through a receiver. The ear mold couples the hearing aid to the ear and directs the amplified sound into the ear's external canal. Power is supplied by a 1.3 or 1.5 battery. Malfunction can occur in any of the components. The problem is exacerbated when many school children hesitate to bring problems to anyone's attention. A hearing aid monitoring program would alleviate problems due to malfunctions and would meet the mandates set forth in Public Law 94-142, which ensures the proper functioning of hearing aids of school children. The best time to check hearing aids is just before or after lunch. A detailed hearing check procedure should be followed. Proper fit helps to assure that the child will not lose the hearing aid. Appendices include diagrams of various types of hearing aids, ear molds, and a hearing aid stethoscope and voltmeter used in hearing aid checks. (LP)

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Hearing Aids and Hearing Impaired Students in Rural Schools

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Hearing Aids and Hearing Impaired Students in Rural Schools

Generally, most people who have difficulty hearing can obtain some benefit from a hearing aid. The amount of benefit depends upon the nature of the hearing loss, the attitude and personal characteristics of the individual, the effectiveness of the hearing aid fitting, instruction in use of the instrument, and of course, the condition of the hearing aid itself. Hearing aids do not "correct" hearing as eye glasses correct vision, they are a tool with much depending upon the skill with which they are used. The effective use of a hearing aid requires effort, it does not passively correct hearing. This effort coupled with the "hassle" of putting it in the ear, maintaining it, and paying for it are on the debit side of hearing aid use. An effective hearing aid fitting is dependent upon the benefit gained from use outweighing the personal disadvantages. This being the case, the probability that a child will benefit from his hearing aid will increase with a reduction in disadvantages and/or increase in benefit. A major cause of decreasing benefit as well as increasing aggravation is hearing aid dysfunction. This paper will describe functions of the various components of hearing aids, and a procedure to detect hearing aid dysfunction.

Hearing aids come in a variety of shapes, sizes and styles* (See Figure 1). All of them have a number of things in common, that is regardless of differences, each hearing aid must have some basic components. Each component has a specific function which is necessary for the system to operate effectively. These will be discussed separately below.

Microphone: The function of the microphone is to transduce (change in form) acoustical energy to electrical energy. The microphone consists of a diaphragm which is a thin plate that moves in response to and in proportion to the pressure variations in a sound, and some form of coupling to a mechanism which either produces or modifies an electrical signal in a manner proportional to its' movement. We better run through that again. The diaphragm is displaced by the pressure variations in a sound. The diaphragm is coupled to some device capable of producing or modifying an electric current. The result is that the device produces or modifies a current proportional to its displacement which is dependent upon diaphragm movement which is dependent upon pressure variations of the acoustic

*By far the most common type of hearing aid found in schools is the behind the ear type. In the ear types are rarely used with children due to rapid growth, i.e. with the ear mold an integral part of the hearing aid, the child would have to be without amplification while a new mold is made.

signal. In this manner an electrical analogue of the original sound is produced.

Amplifier: The amplifier uses the very small electrical signal from the microphone to control or modulate a much larger electrical signal. The result of this process is a larger electrical analogue of the electrical output of the microphone. Usually this amplification process occurs through several stages to achieve the desired magnitude.

The amplifier is the primary user of current in a hearing aid. How long a battery lasts (battery life) is dependent primarily on the amplifier. In most hearing aids, the amount of current drain is constant at all volume control settings. That is, how high the hearing aid is "turned up" does not affect how long the batteries will last. However with some high output hearing aids that use a "push-pull" type amplifier, the current drain increases with increased volume and with increases in level of input (sound level at the microphone). We will see in the next section that we can determine fairly accurately how many hours of use a battery will provide with most hearing aids.

Power supply: The power supply for most hearing aids is a 1.3 to 1.5 volt cell or "battery." The cells are usually "button" cells, which are very small in size, but some body type hearing aids use standard AAA alkaline cells or similar types. The power supply furnishes the electrical power needed by the microphone and amplifier to produce and amplify the electrical analogue of the acoustic signal.

Table 1. Range of battery capacities in milliampere hours for various battery sizes.

Battery Capacities Rated in Millampere Hours

<u>Battery Size*</u>	<u>Mercury</u>	<u>Zinc Air</u>
675	180-190	400
312	45	
13	85	170
41	150-160	300

*Hearing aid size is indicated by a number. Manufacturers of batteries often add letter designations too numerous to describe here, i.e. size 13 may be DA13, AC 13E, R13ZA and on and on. The most important characteristic for our purposes is the number. We need to be sure that the battery is of the size required by a particular hearing aid and this is what the number indicates.

The greater the amount of current drawn, the more rapidly the battery will "die." Since batteries are fairly expensive, battery life is a concern. Hearing aid manufacturers usually list the battery current that a particular model of hearing aid uses. The battery current is reported in milliamperes (mA). To determine how many hours a battery will last in a particular hearing aid we must divide

the battery capacity listed in milliamperere hours by the current drain reported by the manufacturer. The battery capacity varies with the type of battery used. For instance a 675 mercury cell has a capacity of 180 to 190 milliamperere hours, if the reported current drain is 1.0 mA then we simply divide 180 milliamperere hours (to be conservative) by 1.0 milliamperes and come up with 180 hours of use per battery. Other rated battery capacities are shown in Table 1. The current drain for any particular hearing aid may be obtained from the manufacturer or the audiologist or hearing aid specialist who dispensed the hearing aid. If batteries are not lasting as long as we estimate from the above calculations, it is important to find out why. The family may not be turning the hearing aid off after it is removed at night, or there may be no off position on the mode selection switch in which case the battery compartment should be opened when not in use, or there may be a problem in the hearing aid requiring return to the manufacturer. In any case the difficulty should be identified and corrected.

Hearing aid batteries are designed to maintain a constant or nearly constant voltage over their life and then lose it rapidly once the potential is used. This characteristic of batteries can pose a problem. For instance, a battery can be fine in the morning and be expired by noon. For a child in school this can result in half a day of frustration and missed information if the difficulty is not identified and corrected by replacing the "dead" battery. Hearing aid batteries should be replaced when their voltage reaches 1.2 volts or less. (Voltage checks will be discussed and/or belabored later.) Which brings up an important point. When something is replaced it implies that we have two items - that being replaced or replacee and that which has replaced the replacee - the replacor (a little humor here). In the case being discussed, the thing that has been replaced is a battery which we must now do something with. What we do with it is an important consideration. Ingestion of spent batteries can cause severe esophageal burns or even death. It is very important to keep them out of reach of children.

Volume control: The volume control is a variable resistor which can reduce the amplitude of the electrical analogue of the acoustic signal which is developed by the amplifier. It is very similar in function to the volume control on a radio or TV, and serves the same purpose, i.e., to regulate the volume of sound to a desirable level.

The volume control on hearing aids is not linear. That is, as the control is turned up or down the resultant increase or reduction in the electrical analogue of the acoustic signal may not be the same for a given amount of rotation at all levels. Typically, a relatively small movement of the volume control at lower settings results in a larger change than the same amount of movement at higher settings. Some volume controls have numbers on them. These numbers are good as a guide to what setting we may want to use for a particular hearing aid worn by a child or other persons not capable of adjusting the output for themselves. The numbers are not standardized among hearing aids or on different hearing aids of the same model. The point here is that a setting of "2" on a particular hearing aid does not result in the same output as a setting of "2" on another hearing aid. The optimal setting must be determined for each hearing aid independently.

Receiver: The receiver is analogous to the speaker on a radio or TV. It transduces the electrical signal into an acoustic signal. This component then completes the transduction/amplification cycle, that is, the original acoustic signal was transduced into an electrical analogue by the microphone, amplified, adjusted by the volume control, and now is conducted through a wire coiled around a metal core creating an electromagnetic field that is proportional to the strength of the electrical signal. The magnetic field fluctuates in strength in exactly the same manner as the electrical signal thus moving a metal diaphragm which in turn compresses and rarifies adjacent air producing an amplified acoustic signal.

Ear mold: the ear mold couples the hearing aid to the ear. The vast majority of ear molds are custom-made from an impression of individual ears in order to insure a snug and comfortable fit (See Figure 2). The ear mold may be made of hard material such as lucite or a variety of soft materials. In addition to coupling the hearing aid to the ear, i.e., directing the amplified sound into the external canal, the ear mold is often modified so that it alters the quality of the sound. A common alteration of this type is venting. This consists of drilling a small hole in the ear mold alongside of or into the sound channel. Venting allows some low frequency energy to escape from the external canal and reduces the feeling of fullness that some hearing aid users experience. Generally, the larger the vent, the more low frequency energy escapes from the external canal. This alteration is often used with persons with hearing that is normal or near normal for low frequencies and a hearing loss in the higher frequencies.

There are many different types of ear molds. Each type has advantages and disadvantages in both acoustical properties and cosmetics. Regardless of the type of ear mold used, it is important that it fit properly. If the fit is too tight, it will be uncomfortable and can result in blisters or very raw, sore spots on the auricle or external canal. A loose fitting ear mold is a major cause of feedback squeal. Feedback commonly results from sound escaping from the external auditory canal, getting back to the microphone and being reamplified. The repeat amplification drives the hearing aid assembly to vibrate at its resonant frequency, producing a loud squeal. A loose fitting ear mold allows a considerable amount of sound to escape from the external canal, which often results in this annoying squeal. Methods of determining what to do about feedback are discussed under hearing aid check procedures later.

In addition to the components outlined above, many hearing aids have additional controls and/or circuits that serve specific purposes. One common added attraction is a telephone pickup. Hearing aids with this option have a position marked "T" on a selector switch. When in this position, a coil of wire replaces the microphone as the primary transducer. How in the world can a coil of wire replace a microphone? you ask. Well, it turns out that telephones have magnetic receivers similar to receivers in some hearing aids as described above. The electrical input produces an electro-magnetic field that changes as a function of the change in strength of the electrical input. The fluctuating magnetic field causes a metal diaphragm to move back and forth compressing and rarifying the adjacent air producing an acoustic signal. The magnetic field produced in the telephone receiver spills over or leaks to the surrounding area. When the telephone pickup coil

is suspended in this magnetic field surrounding the telephone receiver, the fluctuating magnetic field induces (hence the term "induction") a current to flow in the telephone pickup coil. This induced current varies in proportion to variations in strength of the magnetic field radiating from the telephone receiver. The magnetic field in the telephone receiver varies proportionally with the strength of the electrical input to the telephone receiver, which is an electrical analogue of the acoustic signal on the other end of the line. Therefore the electrical current induced in the telephone pickup is an analogue of that same acoustic signal, which is amplified and transduced into an acoustic signal at the hearing aid receiver. Real clear, right? In any event, when the telephone pickup alone is activated, the hearing aid responds only to magnetic signals. Airborne sound is not amplified at all. Some hearing aids have a means of activating both microphone and telephone pickup circuits at the same time. This mode of function is normally denoted by an "MT" position on the selector switch and allows the wearer to hear amplified environmental sound and sound produced via transduction of magnetic signals. In addition to aiding an individual to hear telephone messages, the telephone pickup has application with some auditory trainers.

As is the case with any man-made device, hearing aids can and do malfunction. A breakdown may occur at any stage in the processes performed by the components described above. Several surveys of hearing aids worn by students in our schools have been reported over the past twenty years. Results of these studies have varied somewhat, but nearly all have found that about half of the hearing aids surveyed were not functioning properly. This is clearly an unacceptably large proportion.

The magnitude of this problem in our schools is accentuated by the point that many younger children hesitate to bring the difficulty to anyone's attention for any number of reasons. The result is that these students go through the school day, or several days in some cases, without benefit of amplification. It has been demonstrated that a daily hearing aid check can reduce the prevalence of malfunctioning hearing aids considerably.

In light of the consistently high prevalence of malfunctioning hearing aids reported in our schools, indications that a hearing aid monitoring program can be effective in minimizing the problem, and the notion that the hearing impaired child will live and learn most adequately when his or her hearing aid is functioning optimally, provisions to insure hearing aid monitoring have been legislated. Public Law 94-142 mandates that "Each public agency shall insure that the hearing aids worn by deaf and hard-of-hearing children in school are functioning properly." Unfortunately, neither PL 94-142 nor most states' interpretations of this law make provisions for implementing hearing aid monitoring. Subsequently, the vast majority of public school professionals have no training in performing a hearing aid check. In many cases, the public school personnel are placed in a situation where they are required by law to perform a function that they have not been trained to perform. An outline of a hearing aid check procedure follows.

A Hearing Aid Check Procedure

To perform the hearing aid check you will need a voltmeter and a hearing aid stethoscope. These tools are shown in Figure 3.

1.0 Removal of hearing aid from child's ear:

- 1.1. Turn mode selection switch to "T" (telephone) or "O" (off) position. This step precludes production of a feedback squeal as the ear mold is removed from the auditory canal. It is preferable to use the mode selection switch as opposed to the volume control when possible so we can check the volume control setting that the child is using. When we find that the child has the volume control turned very low - or very high, we must find out why, or refer to the audiologist or hearing aid dealer who fit the hearing aid to find out why.
- 1.2 Gently rotate the helix portion (See Figure 2) of the ear mold slightly posteriorly to free the top portion of the ear mold. When the helix portion of the ear mold is free of the helix, tip it slightly outward away from the head then rotate it anteriorly and simultaneously pull away from the head. The ear mold should slip out of the canal smoothly. Sometimes it is necessary to use a finger to push against the inner portion of the auricle to "pop" the ear mold out. Be very careful not to try to "dig" the mold out - especially if you have lethal length fingernails.

2.0 Visual inspection:

- 2.1 Inspect the ear mold for ear wax in sound or vent channels, and/or cracks or rough edges. If the vent or sound channel is occluded with ear wax, it may be removed with a small piece of wire or a small paper clip - in spite of wide spread advocacy, most pipe cleaners just don't fit through the channels. The ear mold may be cleaned with warm water and soap, however, it is very important to rinse and dry it thoroughly if this is done. Soap film left on the ear mold can irritate the skin of the auricle and enable the mold to loosen or slip out of the ear canal. Any water droplets not removed from the sound channel or tubing can result in a very distorted signal.
- 2.2 Inspect the hearing aid case for cracks or other signs of trauma. Although the ingenuity of parents and children in "patching up" damaged hearing aids with tape, wire, and unfortunately "super glue" at times, is admirable, damaged casings should be evaluated by the hearing aid dispenser to determine whether repair is necessary.

3.0 Battery check:

- 3.1 A voltmeter provides the most accurate means of checking a battery (or more accurately "cell"). The voltmeter should have a scale sufficient to readily see differences of 0.1 volt. Many voltmeters have scales that are too small or ranges too large to allow for the 1.0 to 1.5 volt measures necessary in checking a hearing aid battery. The voltage of the battery should be between 1.25 and 1.5 volts. If less than 1.25 volts the battery should be replaced. In connecting the leads from the voltmeter to the battery, be sure that the positive lead (marked + or red) is contacting the positive terminal of the battery (marked +) and that the negative lead (marked - or black) contacts the terminal opposite the positive terminal of the battery (often not marked).
- 3.2 When no voltmeter is available, we can get a rough idea of whether the battery is supplying enough power by performing a feedback test. When the hearing aid is turned on in the "microphone" (M) mode and the volume control is rotated to one half or more, a feedback squeal will be heard when a hand is cupped around the hearing aid and ear mold. If no feedback squeal results, the battery may be bad. Since an earmold with sound channel occluded with ear wax or a dysfunctioning or non functioning hearing aid may also result in a lack of feedback squeal, a new battery or one known to be functional should be inserted and the process repeated. If we now get a feedback squeal, it is safe to assume that the original battery was bad, and we can continue with the hearing aid check.

4.0 Listening Check:

- 4.1 Using a hearing aid stethoscope, insert the tip of the ear mold in the flange of the hearing aid stethoscope, and insert stethoscope ear pieces in your ears. Now turn the hearing aid on and insure that it is in the "M" (microphone) position. Turn the volume control up and down while repeating some vocalization such as "testing, testing ..." listening for clarity of signal. Lightly tap the hearing aid and listen for any intermittencies that might indicate a short in the instrument. If any obvious distortion, static, or intermittent "cut outs" are detected the hearing aid should be checked by the audiologist or hearing aid dealer who fit it.
- 4.2 Several writers have suggested that persons performing a hearing aid check have their own ear mold for use in the listening check. It is a very good idea for each person involved in performing hearing aid checks to have their own custom ear mold, but only so they can learn to insert and remove the ear mold and develop a feel for how much pressure they can apply in inserting and removing the mold without causing pain. Using a custom ear mold in performing the listening check is awkward and time consuming. The child's ear mold and tubing must be removed

and that belonging to the person performing the check attached. This done, the check is the same as that described above using a hearing aid stethoscope. In addition to being much more time consuming than using a stethoscope, a personal ear mold cannot be used in checking all in-the-ear, or body type hearing aids without special adaptations.

5.0 When feedback is a problem:

Recall that feedback is often caused by amplified sound escaping from the external canal and getting to the microphone thereby being reamplified over and over again. This drives the hearing aid to vibrate vigorously at its resonant frequency, producing the loud squeal known as feedback. When this occurs the following steps should enable you to determine the general location of the problem to correct it or make an appropriate referral. The feedback check should be accompanied by all of the hearing aid check procedures outlined above.

- 5.1 The first step after noting a feedback problem is to check to determine whether or not the ear mold is properly in place. The helix portion should be tucked under the helix and the concha portion seated. Often, particularly with young children or those not experienced in inserting an ear mold, inserting it properly, and spending a few minutes instructing the child in how to insert it will solve the problem.
- 5.2 If improper insertion of the ear mold is ruled out, remove the hearing aid (see section 1.0), firmly cover the sound channel with your thumb and any vent with your index finger, and turn the mode selector to the "M" position and the volume control to full on. Now cup your free hand around the hearing aid assembly and listen for feedback. If no feedback occurs in this condition, the problem is with the ear mold fit, use of too high a volume control setting, or the venting. The child will most likely need a new ear mold and should be seen by someone trained in making impressions for an ear mold remake.
- 5.3 If feedback does occur in the condition described in 5.2, remove the tubing from the ear hook, place your thumb firmly over the open end of the ear hook and with the mode reflector in "M" position, turn the volume control to full on and listen for feedback. If no feedback occurs in this condition, the problem is most likely a crack in the tubing or leakage around the tubing in the ear mold. The ear mold in this case will need to be retubed, which is a very simple and inexpensive procedure but requires the attention of someone trained to do it who has access to new tubing.
- 5.4 If feedback does occur in the condition described in 5.3, you may remove the ear hook (most unscrew, but others detach in different manners - don't force it!), place your thumb firmly over the opening where the ear hook is attached and with the mode selector in "M" position turn

the volume control to full on and listen for feedback. If no feedback occurs in this condition, the problem should be in the ear hook, most likely a crack or hole in it. A new ear hook should eliminate the problem in this case and can be supplied by most audiologists or hearing aid dispensers.

- 5.5 If feedback is present in the condition described in 5.4, the problem is most likely internal. In this case the hearing aid will probably have to be sent to the manufacturer for repair. The audiologist or hearing aid dispenser handling the repairs should be able to supply a loaner hearing aid for use during the repair period.

Persons trained to correct the problems described above will usually be audiologists or hearing aid dealers. When these services are not readily available, some speech-language pathologists and a few parents of hearing impaired children are able to handle these problems. It is a good idea to determine what resource people are available in your area anytime you have or anticipate having a hearing impaired child in your classroom.

The preceding steps are used with behind the ear or in the ear type hearing aids. When checking a body type hearing aid, the listening check is slightly different. In order to perform the feedback test, the receiver of the hearing aid must be held close to the microphone rather than cupping hands around the instrument as we do with behind the ear types. In addition to turning the volume control up and down and tapping the instrument, we should gently move and bend the cord while listening to detect interruptions in the signal indicating a break in the cord. If these are noted, the cord should be replaced--cords should be the correct length, they come in a variety of lengths, if too long they may be tied in knots or pinned, which often results in breaks, if too short the ear mold may be jerked out of the ear every time the child turns his head! One more point regarding body type hearing aids, it is important to carefully check the microphone during the visual check, to detect any food or dirt that may interfere with sound passage. This is particularly important when the microphone is located on the top portion of the instrument. It is also a good idea to check for clothing rub noises when the aid is worn under clothing. To do this, remove the earmold-receiver combination from the ear and listen to the output without removing the hearing aid body from its pocket, or harness, or whatever, while the child moves normally -- but not too quickly or too far!

General Considerations:

The optimal time to check the hearing aid is just before or after lunch. Coupling the check to some routine event minimizes the chance of forgetting to do it. Using lunch time as the "cue" results in measurement towards the middle of the day. This is important, since hearing aid batteries are constructed to lose voltage very quickly once they reach fairly low voltages, so if a parent checks the hearing aid in the morning, then the teacher checks it just before school, each finding it o.k., it could be dead by noon, depriving the child of amplification for half the day. Hearing aid batteries have another

peculiarity in that one may be just about dead at bed time, then when rested over night it can recover to a full charge, but it deteriorates very rapidly during use. This may result in a check first thing in the morning that shows all to be fine, with a dead battery by late morning or early afternoon. It is a good idea to obtain an extra battery for hearing aids from the parent, then if it is not needed over a month or so, rotate it i.e. take the battery out of the child's aid for a spare and use the original spare - this prevents wasting the battery, since they will deteriorate over time even if not used.

One last general comment -- it is real helpful to observe the hearing impaired child on the playground and in the classroom, noting how the hearing aid fits. We have all seen children with their hearing aid flopping around on the side of the head, held only by the ear mold. The tubing should be cut to a length that allows the ear hook to rest on the junction of the auricle with the side of the head. If it is too short, it will constantly loosen the ear mold resulting in feedback squeal. If too long, the hearing aid will not stay behind the ear and normal movement will result in it's swinging around bouncing from one point to another, often dislodging the ear mold and joining the host of its brethren forever lost on playgrounds, ground into the earth by thousands of small feet.

I hope that the preceding has been of some help in familiarizing you with the basics of hearing aids. The hearing aid check procedure may seem somewhat overwhelming at first, but after a few applications it should look a lot easier. As is so often the case in rural education, the hearing aid check is often a case of "if you don't do it - it won't get done" for the classroom teacher. I hope that the information presented here will help in complying with PL 94-142 and more importantly, in meeting the needs of hearing impaired students in our rural schools.

Recommended Readings:

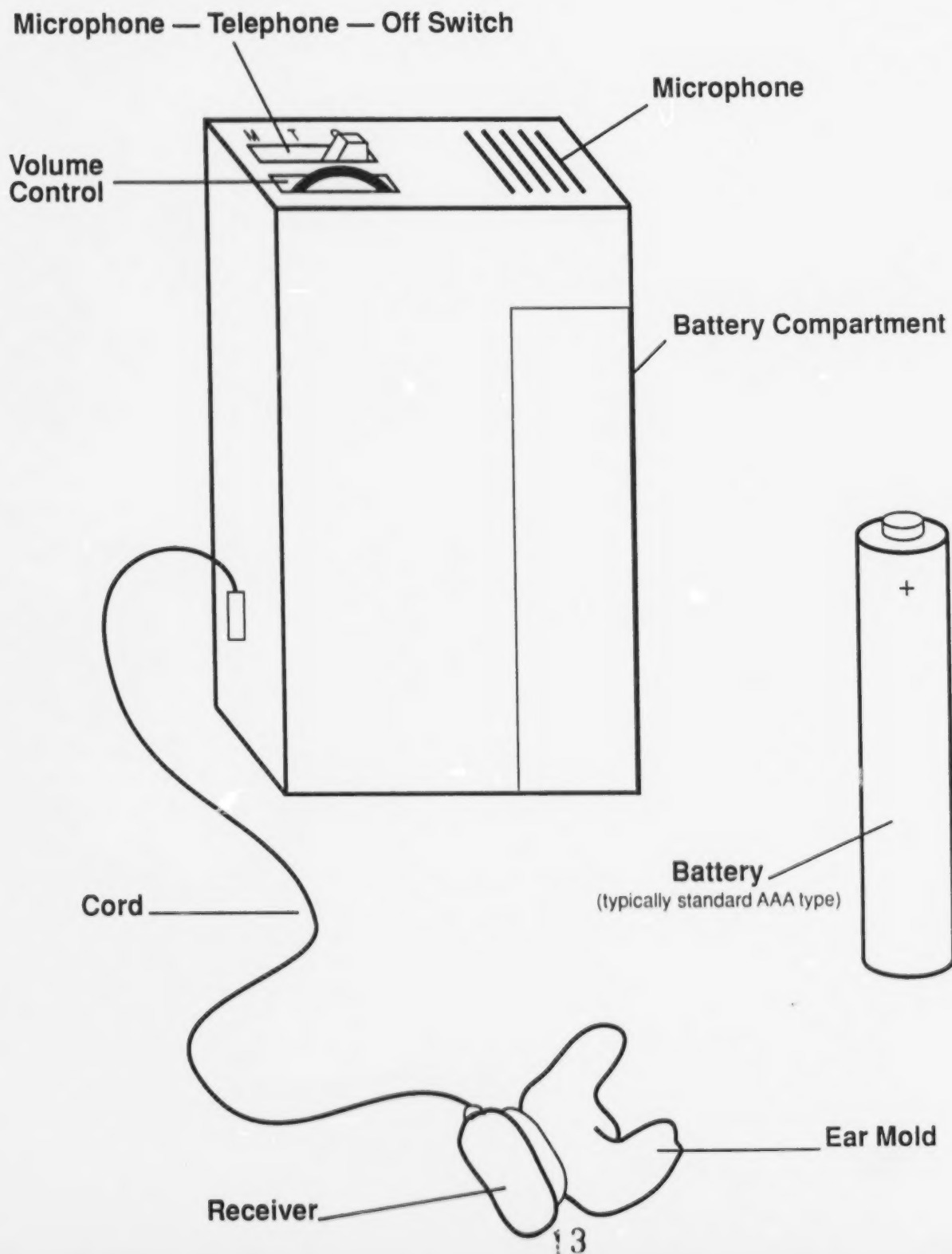
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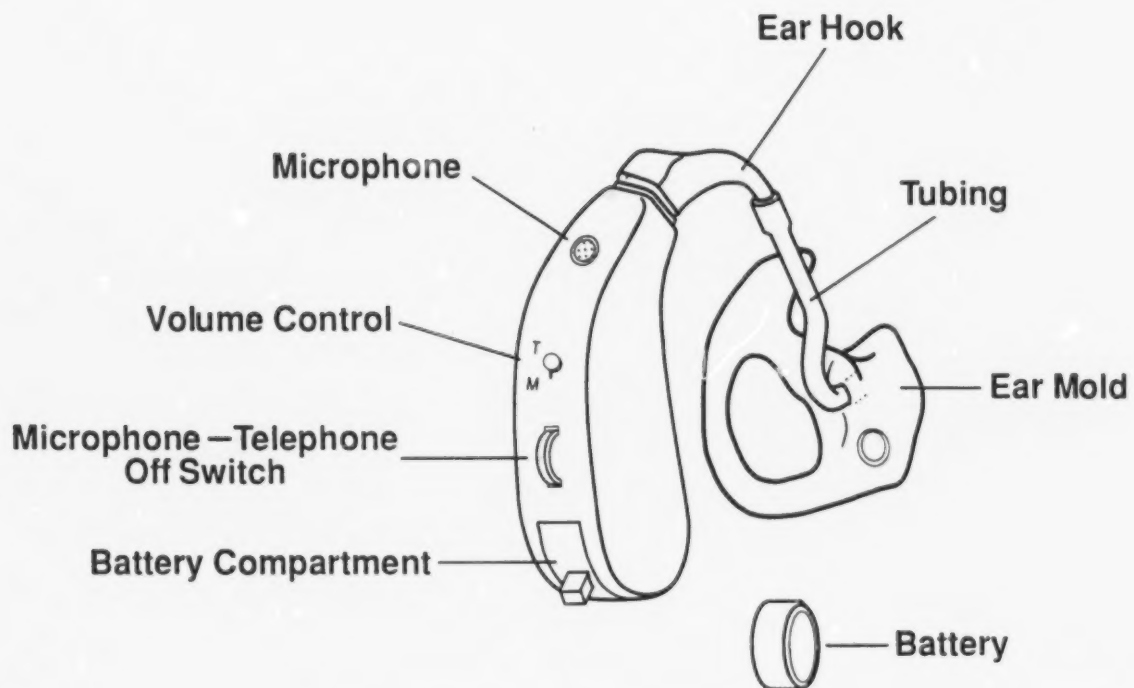
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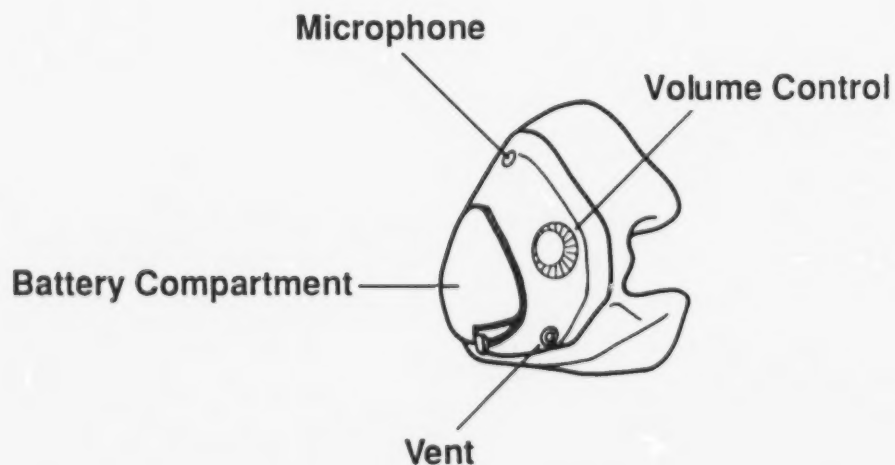
Body Type Hearing Aid



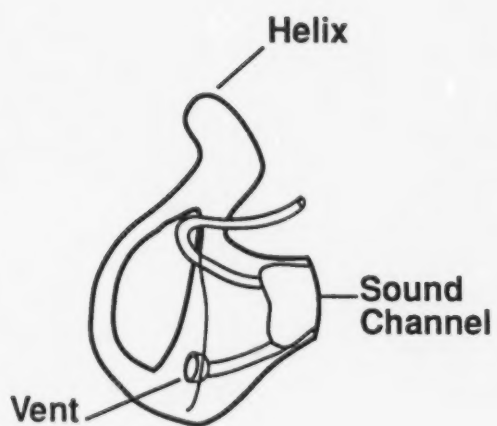
Behind the Ear Type Hearing Aid



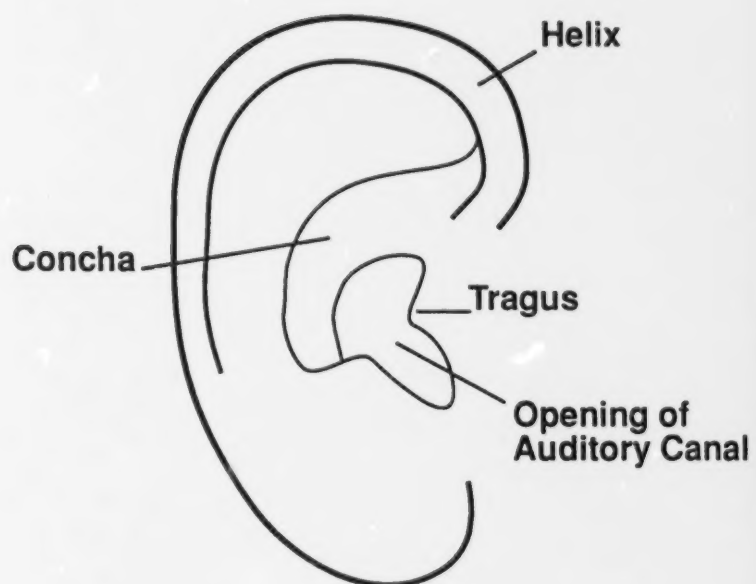
In the Ear Type Hearing Aid



Ear Mold



Auricle



Hearing Aid Stethoscope



Voltmeter

